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Pressure Distribution Measurements on an AVRO Swept Back Wing Model.

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Signed J. R. R.J.T. NATIONAL RESEARCH COUNCIL Sheet 1 of 7

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PRESSURE DISTRIBUTION MEASUREMENTS ON AN AVRO SWEPT BACK WING MODEL

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NOTATION

C_L	-	wing lift coefficient
C_m	-	wing pitching moment coefficient
c_m	-	section pitching moment coefficient
C_N	-	wing normal force coefficient
c_n	-	section normal force coefficient
b	-	span
c	-	local chord
c_{av}	-	mean geometric chord
$\bar{c}$	-	mean aerodynamic chord
p	-	local static pressure
q	-	dynamic head
S	-	wing area
x	-	distance along the chord measured from the leading edge
$\bar{x}_{cp}$	-	distance along the chord measured from the center of pressure to the y-axis through $0.25\bar{c}$.
y	-	distance along the span measured from the center section.
α	-	angle of attack

1. INTRODUCTION

The results of a series of No. 3 Wind Tunnel measurements of the aerodynamic characteristics of a model of an A. V. Roe (Canada) Limited 43° swept-back wing have already been presented (N.R.C. Aero. Memo. 5684-1 to 6). As a further check on the aerodynamic characteristics of this model, pressure distribution measurements were undertaken and the results are presented in this memorandum.

2. MODEL

The basic model dimensions have been given in Reference 1.

Since the model was not provided with surface pressure orifices, the pressure distribution measurements were made by the use of plastic pressure measuring belts. The belt is made up of 23 tubes (0.027 inches in diameter) molded together as a unit to form a belt 0.065 by 1.3 inches. Only 20 out of the 23 available tubes in each belt were adapted for pressure readings. A photograph showing two belts mounted on the wing model is given in Figure 1.

All the holes in the belt were sealed with Tygon primer at one end; the other end was connected to an adapter on the leads from the multiple manometer. Each tube in the belt was provided with a single orifice, the orifices being staggered at one inch on one belt and every half-inch on the second belt. The belts were placed at desired locations on the surface of the wing model and secured in position with cellulose tape.

3. EXPERIMENTAL DETAILS

The pressure distribution measurements were carried out in the N.R.C. No. 3 Wind Tunnel at a tunnel speed of 196 ft./sec. corresponding to a Reynolds Number (based on the mean geometric chord) of 2.2×10^6.

The measurements were made at angles of attack (geometric) of 0, 6 and 12 degrees and zero angle of yaw.

The tests were carried out without tip tanks and without dummy struts. The pressure belts were located along the chord at desired stations and secured in place with cellulose tape. The pressure readings were recorded with the model pitched positively to obtain the upper surface pressure distribution. The model was then pitched negatively to obtain the corresponding lower surface pressure distribution. Although the model is unsymmetrical in its present condition due to spanwise cracks (see Reference 2) the above procedure was deemed satisfactory.

No attempt was made to ascertain the errors which may be involved in using the belt method. However, it was realized that the pressure distribution over the wing surface was probably changed near the belt. The magnitude of the errors involved would be largely dependent on: changes in the local wing profile due to the belt; cleanness of the drilled orifices in the tubes of the belt and the orientation of the belt relative to the local flow direction. Some difficulty was experienced in obtaining a "clean" orifice in the tubes.

4. RESULTS

4.1 Planform Pressure Distribution

The upper surface isobars are shown at angles of attack (geometric) of 0, 6 and 12 degrees in Figures 2, 3 and 4 respectively. The general pattern for $\alpha = 0^\circ$ and 6° is very similar. However, the pattern over the outboard 0.5 span at $\alpha = 12^\circ$ shows a marked difference. The region over which the isobar pattern for $\alpha = 12^\circ$ differs markedly from that shown for $\alpha = 0^\circ$ and 6°, was found to correspond with the region of stall at $\alpha = 12^\circ$ as revealed by the water tunnel tests (to be presented in a separate memorandum) with a similar half-wing model.

4.2 Chordwise Pressure Distributions

The pressure distributions are plotted for eight (0.03, 0.13, 0.25, 0.50, 0.75, 0.88, 0.92 and 0.96 span) spanwise positions in Figure 5 for $\alpha = 6^\circ$ and Figure 6 for $\alpha = 12^\circ$.

There is a reduction of the suction peaks at the tip and center sections. The difference in height of the suction peaks being more pronounced for $\alpha = 12^\circ$ than for $\alpha = 6^\circ$. The suction peaks at 0.03, 0.13, 0.25 and 0.50 span are much lower for $\alpha = 6^\circ$ than for $\alpha = 12^\circ$.

4.3 Spanwise Normal Force Distribution

The results of the chordwise pressure distributions presented in Figures 5 and 6 have been integrated (by planimeter) to obtain the section normal force coefficients.

$$c_n = \int_0^1 \left(\frac{p_{upper} - p_{lower}}{q}\right) d\left(\frac{x}{c}\right)$$

The distribution of the normal force coefficients along the span is shown in Figure 7 for $\alpha = 6^\circ$ and 12°.

The spanwise normal force distribution shows a pronounced bump in the curve at 0.5 span for $\alpha = 12^\circ$. Test results (to be presented in a separate memorandum) showed that at $\alpha = 12^\circ$, the region of separated flow covered the forward 50 percent of the chord at 0.5 span. Where such regions of separated flow occur higher loadings are produced since the airfoil is effectively given a large camber. Furthermore, the water tunnel tests revealed that at $\alpha = 12^\circ$ the separated region covered the entire chord length beyond 0.52 span. Since the sections beyond 0.52 span were completely stalled there was a fall in the spanwise loading distribution as revealed in Figure 7.

By plotting $c\,c_n$ against the span (the curve is not presented in this memorandum) and integrating (by planimeter), the wing normal force coefficient was obtained, where:

$$C_n = \int_0^1 \frac{c\,c_n}{c_{av}}\, d\left(\frac{2y}{b}\right)$$

The results obtained from the pressure distribution are compared with those obtained by force measurements. The comparison is shown in Table 1.

TABLE 1.

α	$C_n \cos\alpha$ (From Pressure Distribution)	C_L (From Force Measurements)
6°	.342	.320
12°	.663	.711

4.4 Centers of Pressure

The position of the center of pressure along the span is given in Figure 8 for $\alpha = 6^\circ$ and 12°. The coordinate x/c gives the position of the center of pressure, measured from the leading edge, referred to the local chord.

At $\alpha = 6^\circ$ the center of pressure locations deviate only slightly from the 20% chord line. At $\alpha = 12^\circ$ the center of pressure location deviates only slightly from the 20 percent chord line over the inboard 0.5 span but moves backwards up to the 40 percent chord line at 0.8 span and then moves forwards again over the remainder of the span.

4.5 Pitching Moment Distribution

The section pitching moment coefficients about the y-axis through 0.25 $\bar{c}$ have been obtained by using the expression:

$$c_m = c_n \frac{\bar{x}_{cp}}{c_{av}}$$

The mean aerodynamic chord for this model is

$$\bar{c} = \frac{2}{S}\int_0^{\frac{b}{2}} c^2\, dy = 23.8 \text{ inches}$$

Figure 9 shows the section pitching moment coefficient distribution along the span. The absolute values of the pitching moment coefficients increase with increasing distance from the center of the wing since these values are proportional to $\frac{2y}{b} \tan \phi$ where ϕ is the sweep-back angle of the leading edge.

By plotting $c_m\left(\frac{c}{c_{av}}\right)^2$ against the span and integrating (by planimeter) the wing pitching moment coefficient was obtained, where

$$C_m = \frac{c_{av}}{\bar{c}}\int_0^1 c_m\left(\frac{c}{c_{av}}\right)^2 d\left(\frac{2y}{b}\right)$$

The results obtained are shown in Table II.

TABLE II

α	C_m 0.25$\bar{c}$
6°	0.0077
12°	0.010

These computations were repeated in order to obtain C_m 0.52 c_{av} and the results obtained are compared with those obtained by force measurements. The comparison is given in Table III.

TABLE III

α	C_m 0.52 c_{av}	
	From Pressure Distribution	From Force Measurement.
6°	0.084	0.063
12°	0.165	0.131

5. REFERENCES

1. E. B. MacCuish — Preliminary Wind Tunnel Tests on a Model of an A. V. Roe (Canada) Swept Wing. N.R.C. Aero. Memo. 5684-1, 21 March, 1950.

2. J. Ruptash — A Check on the Symmetry of an Avro Swept Back Wing Model N.R.C. Aero. Memo. 5684-6, 24 August, 1950.

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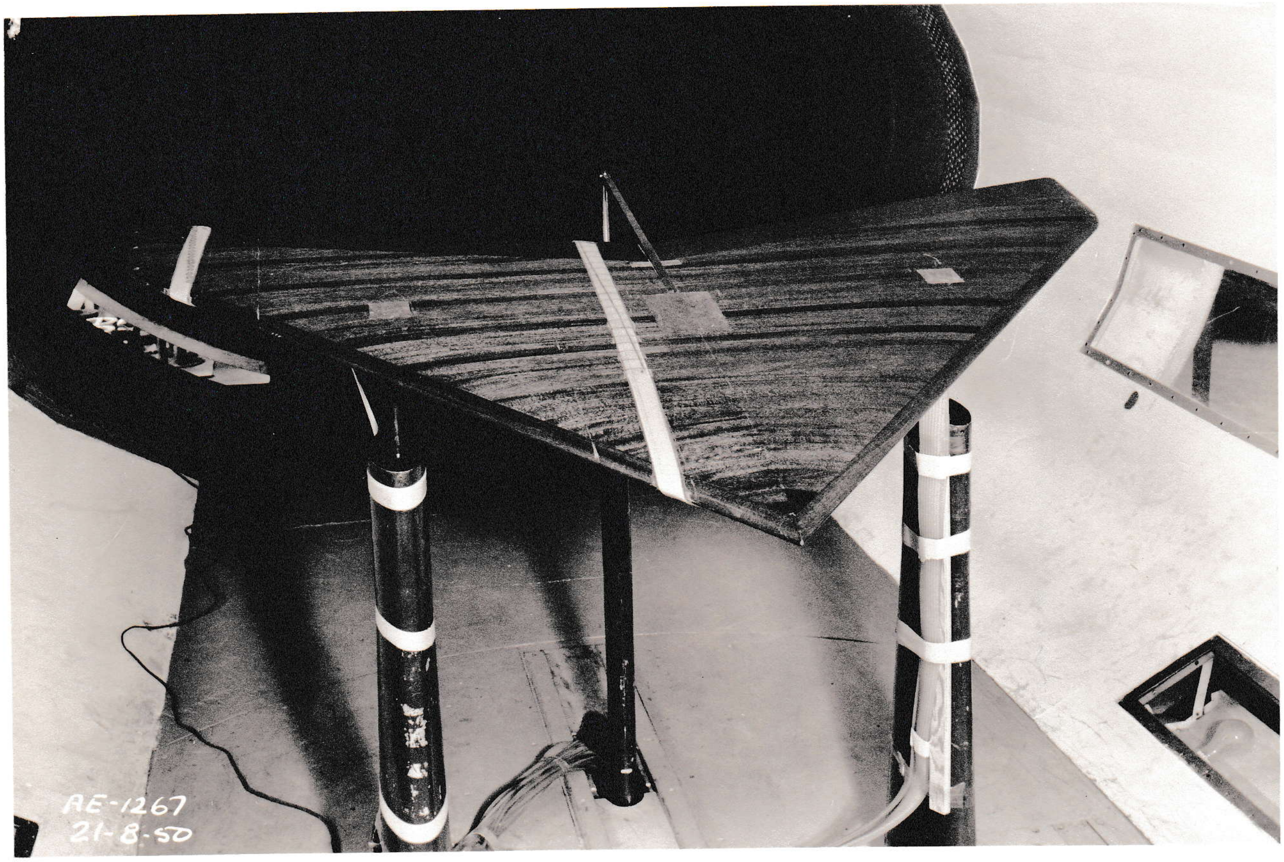
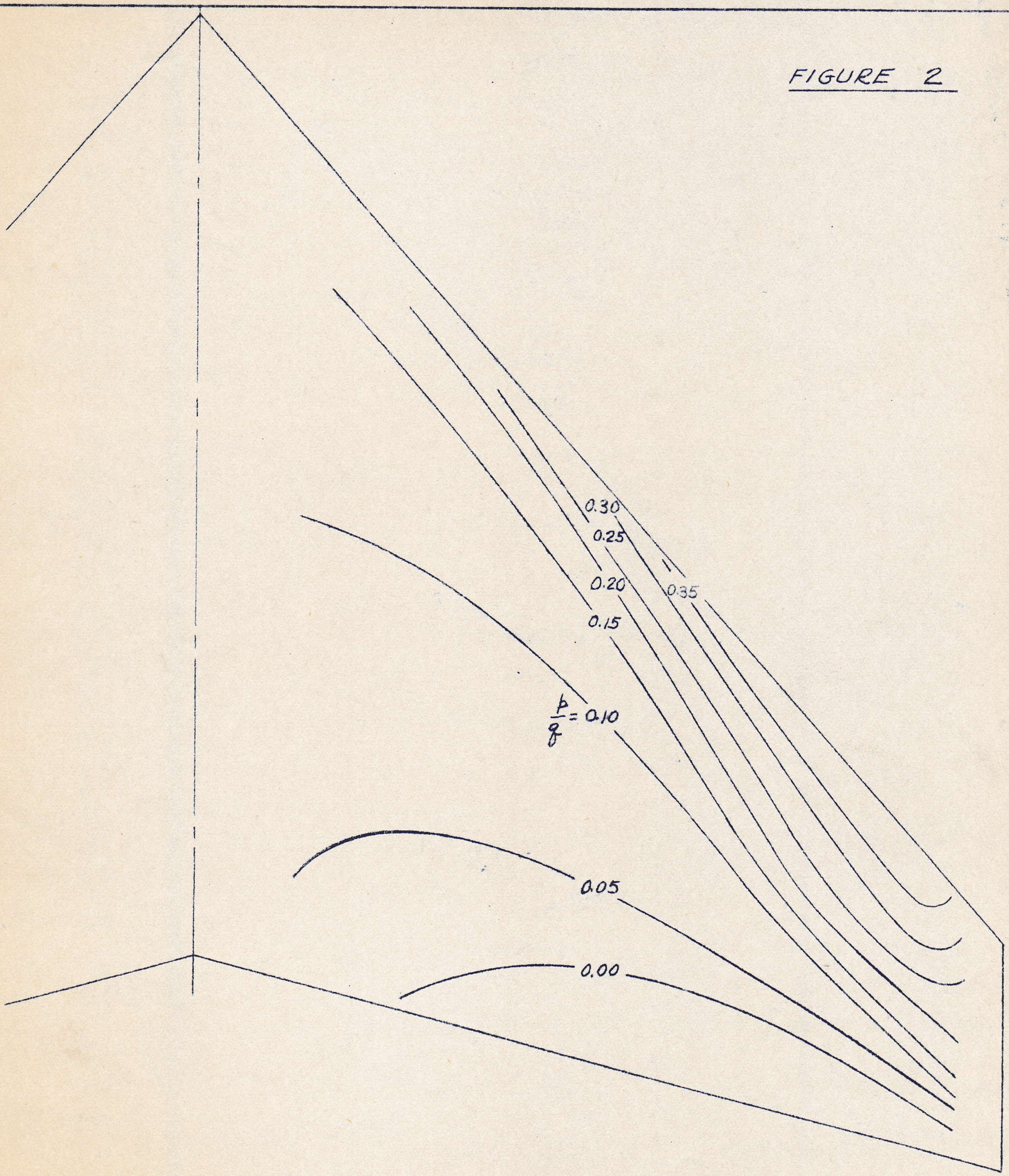
FIG·1



PRESSURE BELT INSTALLATION ON

THE AVRO SWEPTBACK WING MODEL

FIGURE 2



PRESSURE DISTRIBUTION-
ISOBARS AT $\alpha = 0°$

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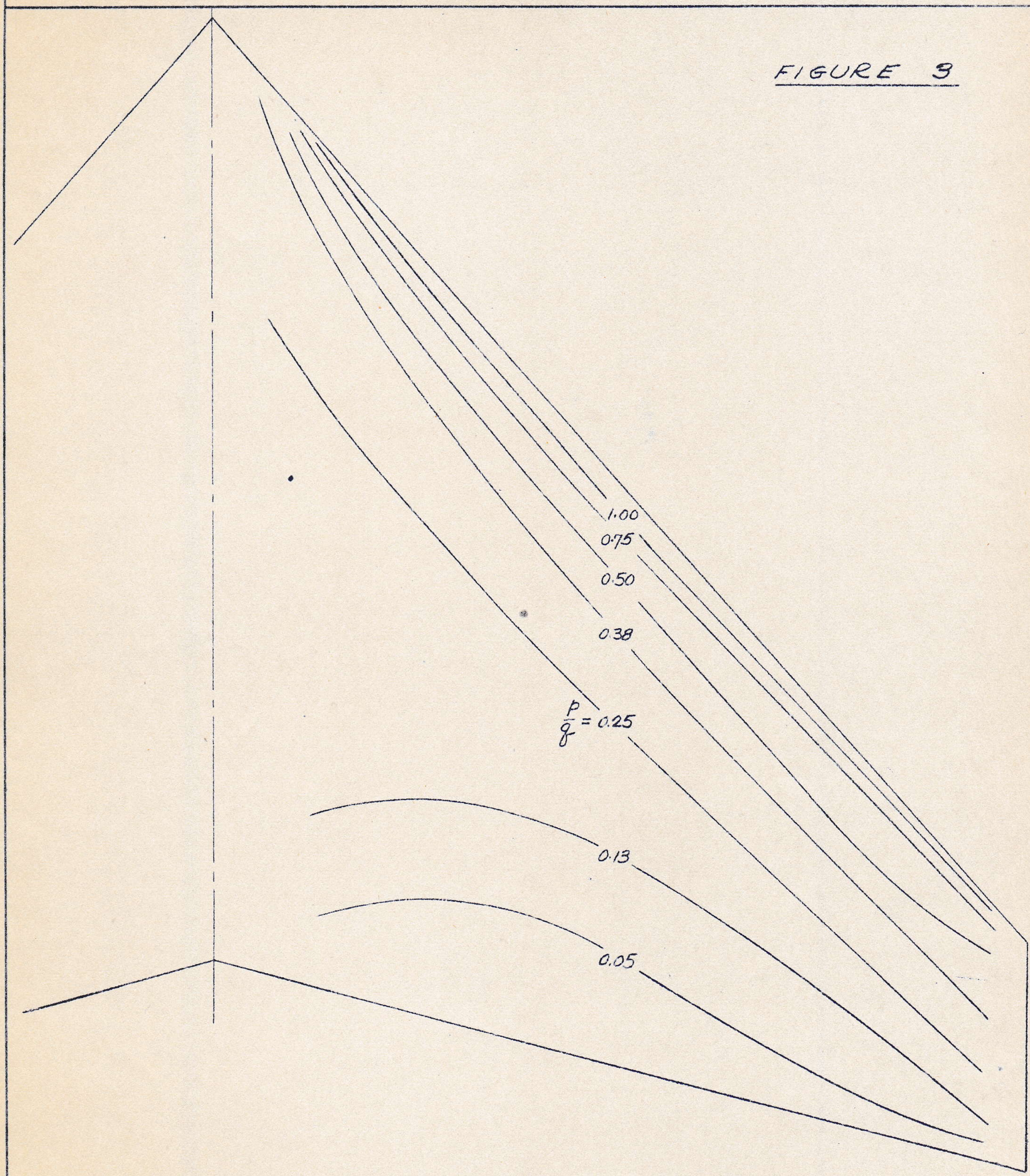
FIGURE 3



PRESSURE DISTRIBUTION-
ISOBARS AT $\alpha = 6°$

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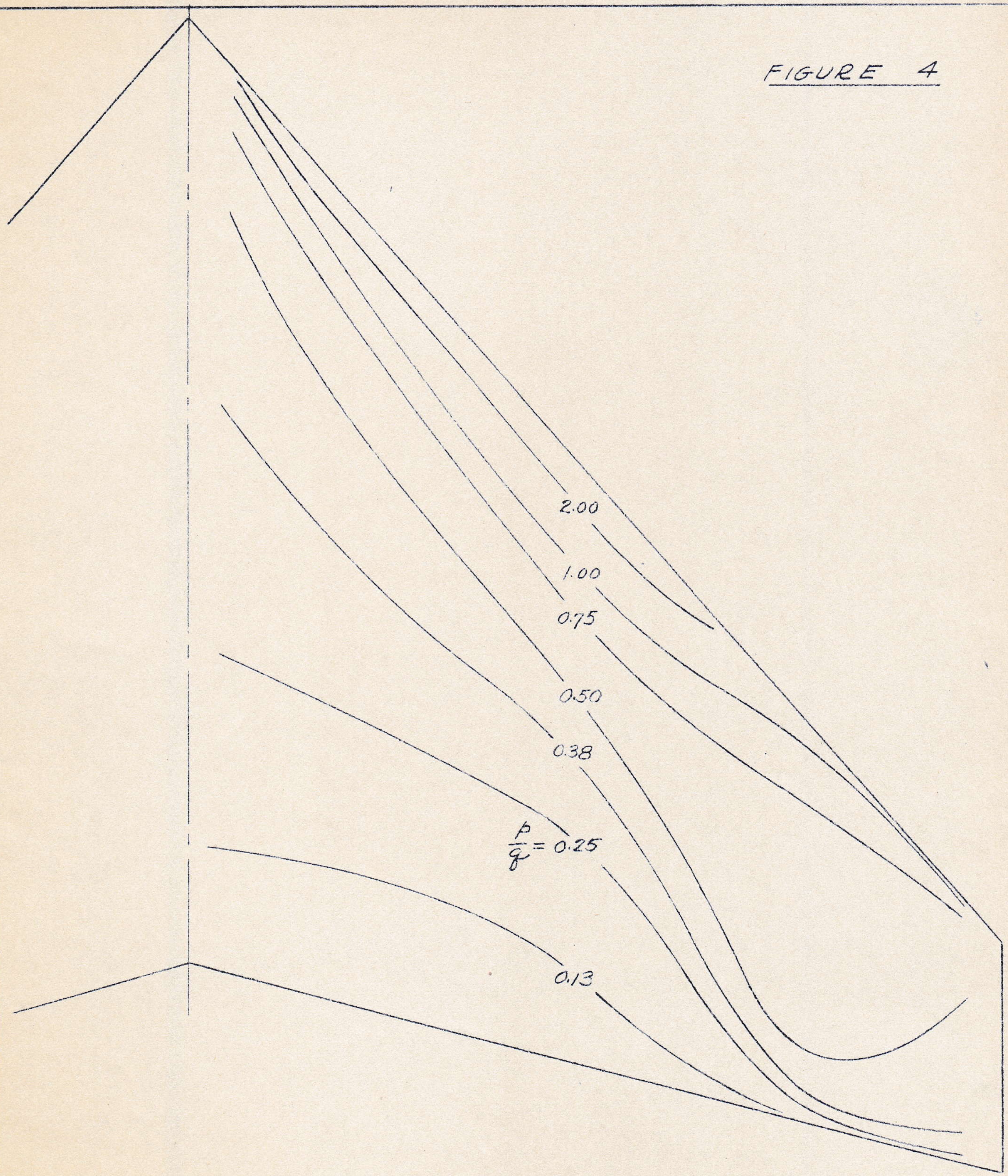
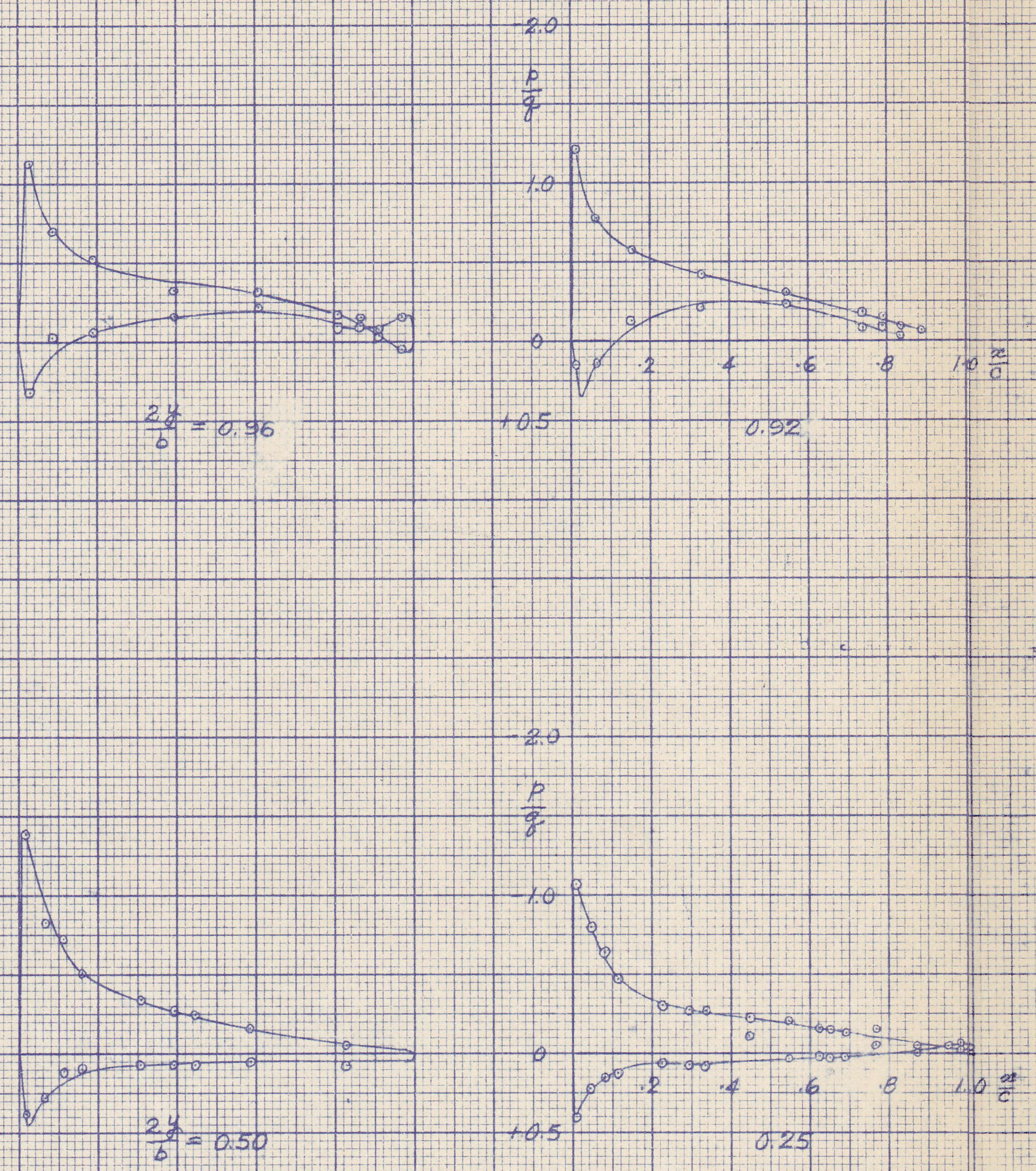
FIGURE 4



PRESSURE DISTRIBUTION-
ISOBARS AT $\alpha = 12°$

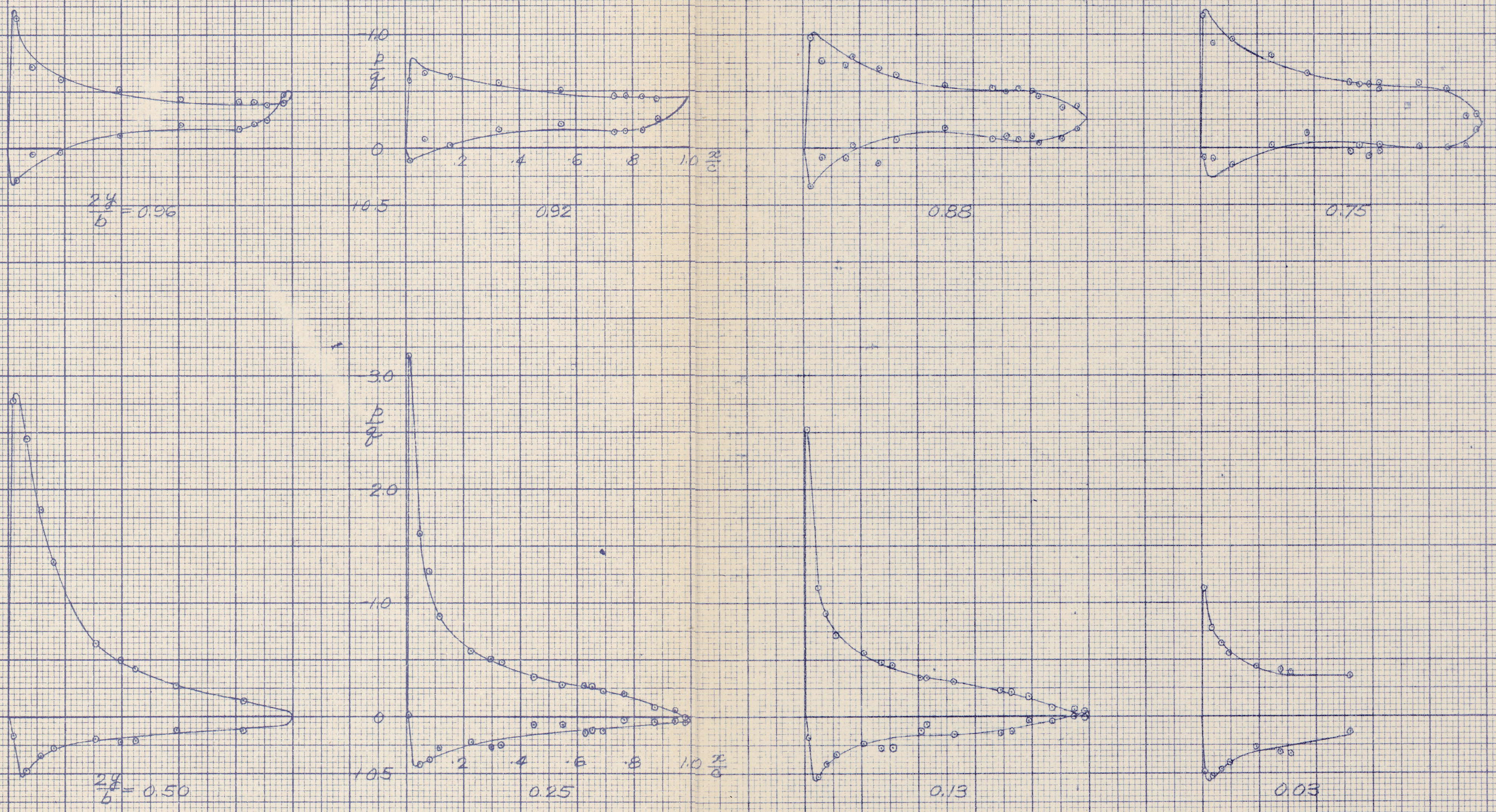
FIGURE 5



CHORDWISE PRESSURE DISTRIBUTION

$\alpha = 6°$

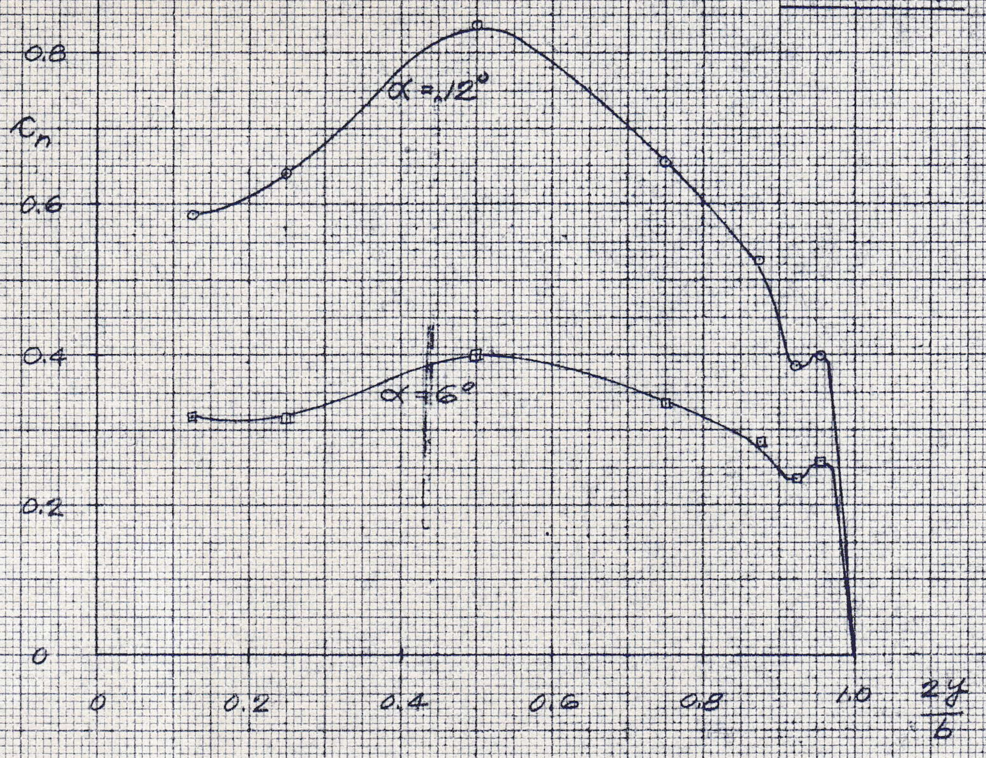
FIGURE 6



CHORDWISE PRESSURE DISTRIBUTION

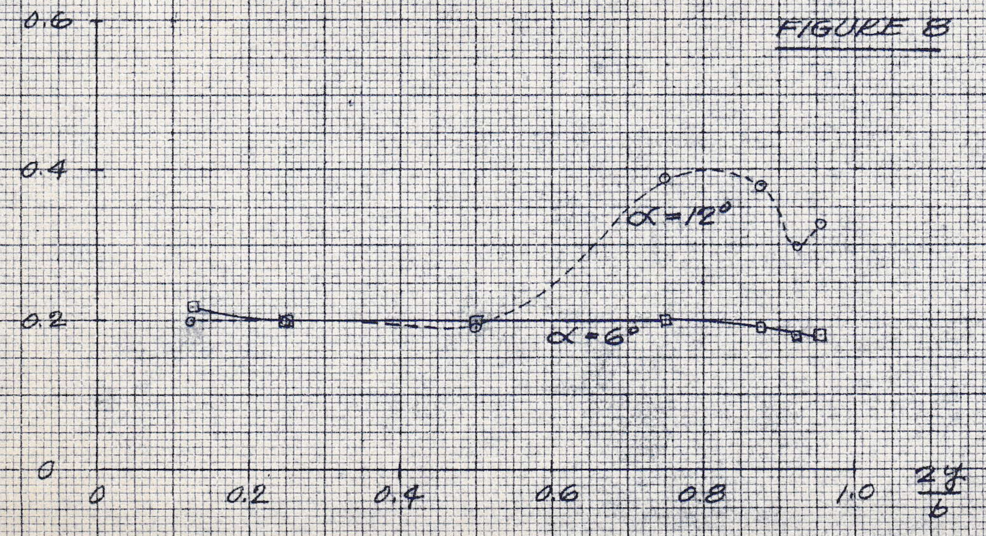
$\alpha = 12°$

FIGURE 7



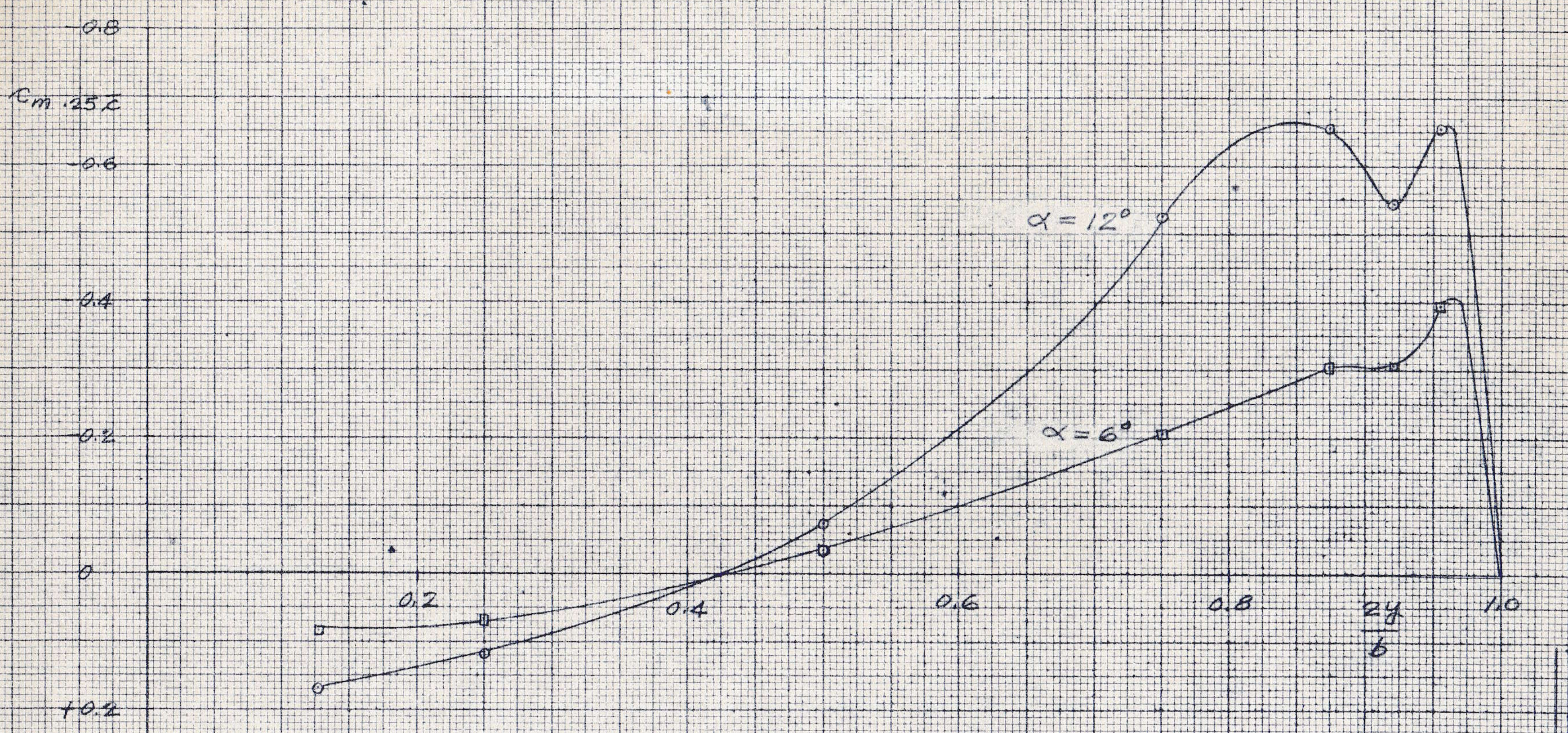
DISTRIBUTION OF NORMAL FORCE COEFFICIENTS ALONG THE SPAN

FIGURE 8



POSITION OF THE CENTER OF PRESSURE ALONG THE SPAN

FIGURE 9



DISTRIBUTION OF PITCHING MOMENT COEFFICIENTS ALONG THE SPAN